NRE*052992*JPB*014NA

FEASIBILITY OF USING NEUTRON RADIOGRAPHY TO INSPECT THE SPACE SHUTTLE SOLID ROCKET BOOSTER AFT SKIRT, FORWARD SKIRT AND FRUSTUM

FINAL REPORT

PART I - SUMMARY REPORT

REPORT SUBMITTED TO:

GEORGE C. MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

N93-11173

Unclas

G3/20 0117771

(NASA-CR-184357) FEASIBILITY OF USING NEUTRON RADIOGRAPHY TO INSPECT THE SPACE SHUTTLE SOLID ROCKET BOOSTER AFT SKIRT, FORWARD SKIRT AND FRUSTUM. PART 1: SUMMARY REPORT Final Report (N Ray Engineering Co.) 12 p

SUBMITTED BY:

NRE Inc.

1422 Vue Du Bay Court San Diego, CA 92109-1931
Phone (619) 488-6610 FAX (619) 488-6812
Sacramento (916) 922-9263 FAX (916) 922-9267

WORK PERFORMED UNDER CONTRACT NAS8-38681

MAY 1992

WPS1\JPB\JPB014NA.REP)

REPORT IS THE NASA PAPER THAT WAS SUBMITTED TO THE WCNR-4

FEASIBILITY OF NEUTRON RADIOGRAPHY FOR SPACE SHUTTLE INSPECTION

J. P. Barton[1], J. W. Bader[1], J. S. Brenizer[2], B. Hosticka[2]

[1] NRE, Inc, 1422 Vue du Bay Court, San Diego, CA 92109
[2] Nuclear Reactor Facility, University of Virginia, Charlottesville, VA 22903

Keywords: aerospace, aluminum corrosion, neutron radiography

ABSTRACT

The space shuttle's solid rocket boosters (SRB) include components made primarily of aluminum that are parachuted back for retrieval from the ocean and refurbished for repeated usage. Nondestructive inspection methods used on these aging parts to reduce the risk of unforeseen problems include x-ray, ultrasonics and eddy current. Neutron radiography tests on segments of an SRB component show that entrapped moisture and naturally occurring aluminum corrosion can be revealed by neutron radiography even if present in only small amounts. Voids in sealant can also be evaluated. Three alternatives are suggested to follow-up this study: take an SRB component to an existing neutron radiography system; take an existing mobile neutron radiography system to the NASA site; or plan a dedicated system custom designed for NASA applications.

INTRODUCTION

Reasons for the U.S. National Aeronautics and Space Administration to consider neutron radiography include verification of (1) pyrotechnics (each Apollo rocket launch required neutron radiography of over 50 explosive devices), (2) gaskets, seals and O-ring, and (3) electrical insulation and bond layers. In this paper, the issue is whether neutron radiography can help protect aluminum structures against unforeseen problems as aging occurs in the reusable parts of the space shuttle solid rocket booster.

The aft skirts, forward skirts and frustums of the SRB are parachuted back and retrieved from the ocean for inspection and refurbishment. Most of these components are already over ten years old, and, with budget constraints, there is the need to plan for continued reuse for as long as possible. The components are made primarily of Type 2219-T87 aluminum, which contains over 6% copper. The structure includes complex arrays of ribs, I-beams, brackets and gussets, held together by rows of steel bolts surrounded by a sealant (typically polysulfide PR-1422 with dichromate coring agent). Especially critical parts include the stiffener rings, holddown posts, thrust vector control and thrust posts. When new, all cavities and faying areas are filled with sealant, but with age and repeated impact on the ocean, cracking and buckling of previously flush surfaces could occur, allowing saltwater entrapment and possibly severe aluminum corrosion. Unforeseen problems could include, for example, corrosion induced along the rows of stainless steel bolts, and multiple sight damage (MSD) a mechanism that caused the Aloha Airlines MSD accident of 1988 that is still incompletely understood.

The aft skirt, forward skirt and frustum are comparable in diameter. Figure 1 illustrates the aft skirt. The outer wall of aluminum has thicknesses ranging from 12 mm to 19 mm. The thickest section of skin and stiffener is 250 mm. The inspections for hidden problems during each refurbishment cycle currently use x-ray, ultrasonics and eddy current methods, but not neutron radiography.

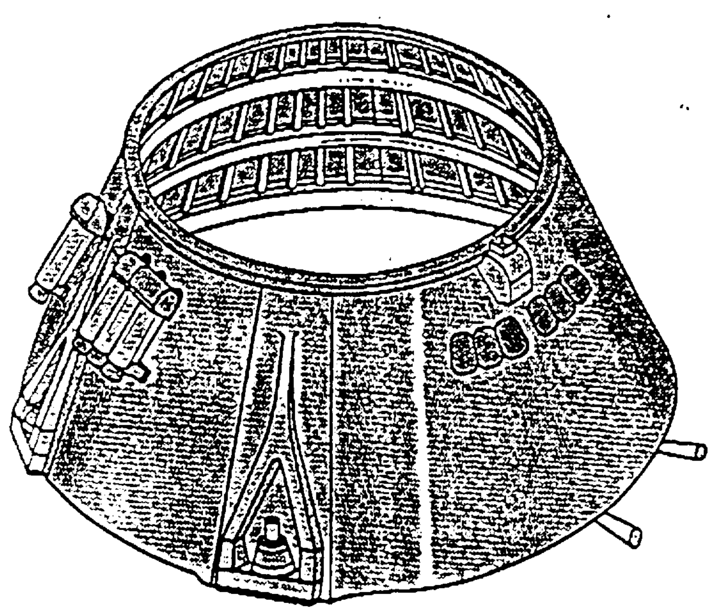
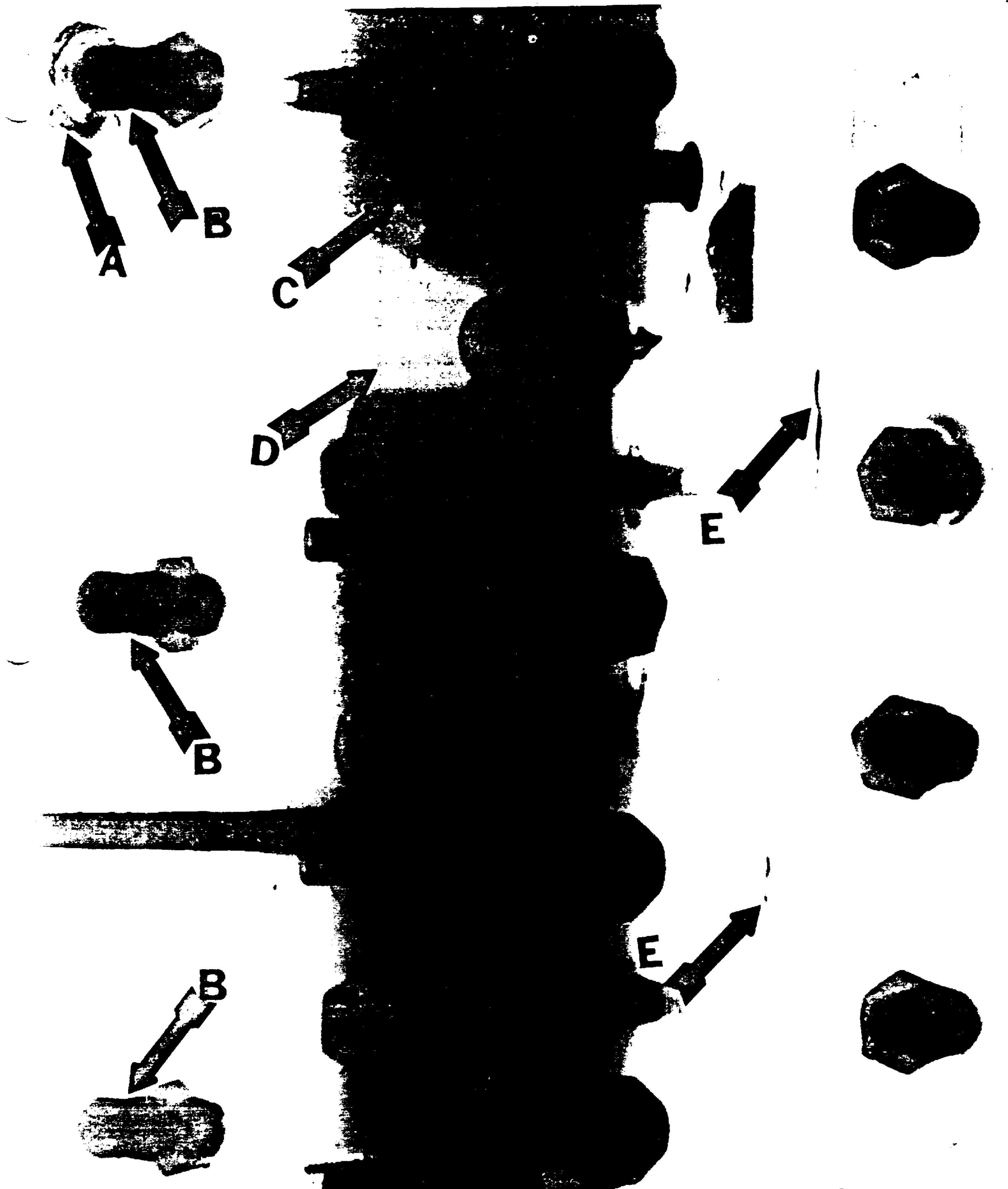


Figure 1: The aluminum aft skirt of the space shuttle solid rocket booster (scale: base diameter is 4.6 m, height 2.6 m, top diameter 3.1m).



ORIGINAL PAGE IS
OF POOR QUALITY

Figure 2: A neutron radiograph taken in 1984 showing a section of an SRB aft skirt after its use on a space shuttle aunch. The arrows point to regions requiring interpretation for possible: (A) faulty ring seals, (B) multi-sight defects in row of steel bolt holes, (C) moisture entrapment, (D) aluminum corrosion on hidden surfaces, and (E) hidden cracks containing corrosion in main block of aluminum (size: picture width [illegible]

DEMONSTRATIONS

The neutron radiograph of an actual SRB aft skirt segment taken in 1984 after retrieval from a launch shows five types of radiographic information (Figure 2). Ways to assist interpretation of such neutron radiographs include: (1) comparison with neutron radiographs at identical angles on a standard or defect free component (2) comparison with x-ray and (3) comparison with follow up neutron radiographs of the same suspect component inspected a few years later to determine if suspect defects have worsened. As an interim step for this feasibility study , we obtained three different segments cut from a disused SRB aft skirt. Tests were conducted at the McClellan Air Force Base Stationary Neutron Radiography System and at the University of Virginia nuclear reactor. The smallest segment used for film NR demonstrations is shown in Figure 3. Using gadolinium-Kodak SR film with a collimator ratio of 100:1, the tests confirmed that neutrons readily penetrate even the thickest sections of this aluminum, and reveal minute details about hydrogenous material in the beam path. For example, if the paint were partially removed, the edge of the paint line could be seen (the paint is Sikkens chromate epoxy-polyamide primer and topcoat). By chance the segment contained hidden naturally occurring aluminum corrosion in two types of geometry: (a) on the roughened edges of a tubular bolt hole radiographed along the axis of the bolt hole such that the corrosion appears as a curved knife edge (Figure 4) and (b) on a flat surface of aluminum (radiographed with the neutron beam perpendicular to the flat surface) (Figure 5). The

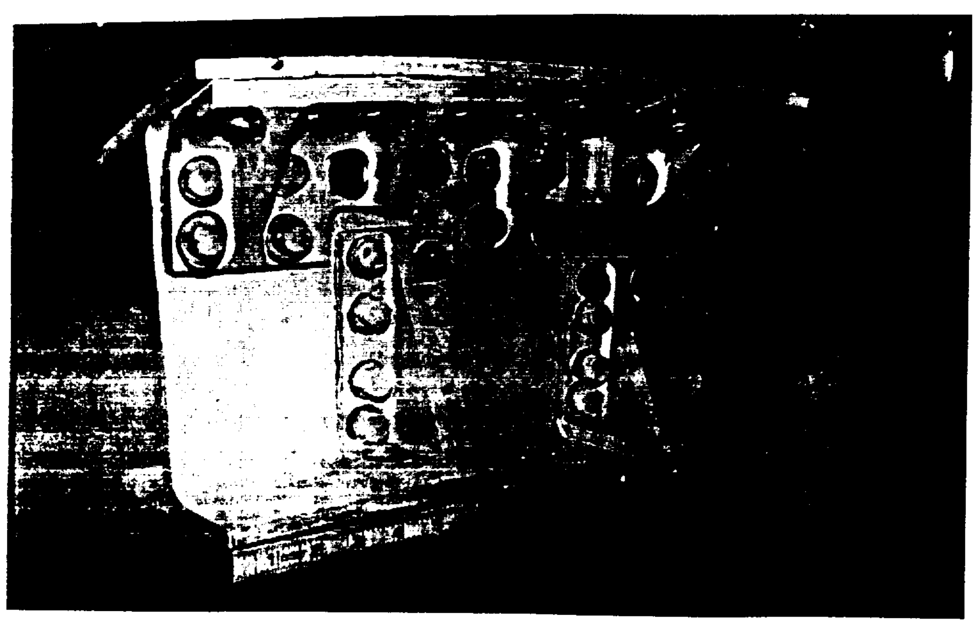


Figure 3: Photograph of a small segment from an aft skirt used in the film method neutron radiography demonstrations (scale: rule in picture is 6" (152mm)).

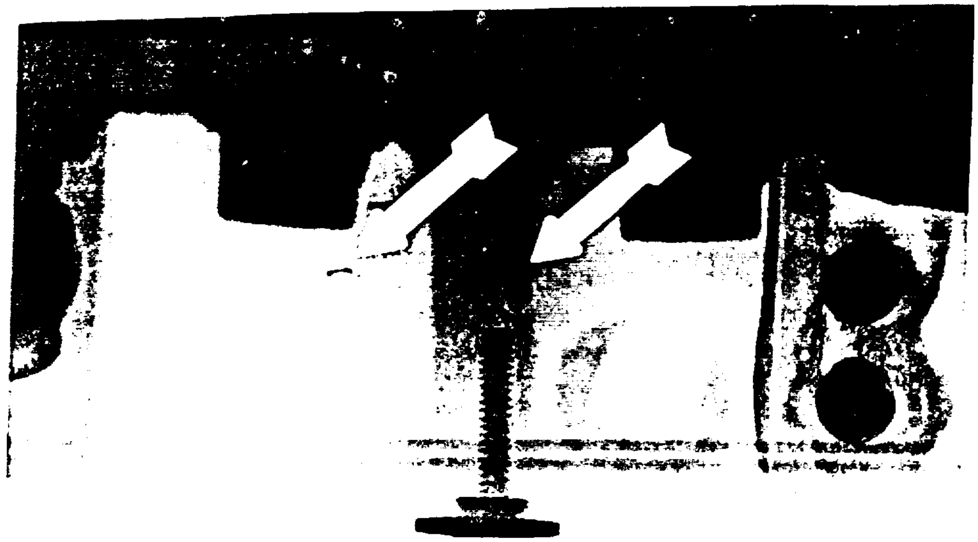


Figure 4: Neutron radiography revealing naturally occurring corrosion on roughened surface of through holes drilled in aluminum SRB segment.

Figure 5
Neutron radiograph revealing
revealing naturally occurring corrosion
on an aluminum surface in plane perpendicular
perpendicular to neutron beam.

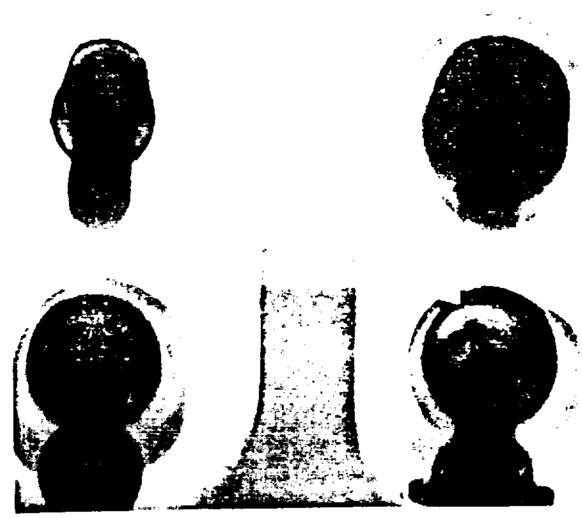


Figure 6
Neutron radiograph revealing
voids in sealant surrounding a steel bolt.

trials demonstrated convincingly that neutron radiography will reveal even such small degrees of hidden aluminum corrosion. Similar neutron radiographs also revealed the severity of voids in the sealant surrounding the steel bolts (Figure 6). Ideally each steel bolt is separated from the aluminum wall of the bolt hole by a protective layer of sealant, but with age the steel might contact the aluminum at points which could lead to corrosion and pitting of the previously smooth wall. Because the sealant will flow into such pits, and because sealant provides very high neutron radiographic contrast, it is predicted that severe pitting of this type could be revealed. Trials with simulated pits supported this theory. Indents on an otherwise smooth bolt hole wall (aluminum-sealant interface) could also indicate corrosion (Figure 2). The demonstration neutron radiographs or the trial segment also revealed corrosion in structural cracks within the new SRB trial segment, supporting the interpretation of the cracks in Figure 2.

TECHNIQUE EVALUATION

Using tapered wedges the neutron radiographic opacity of the aluminum corrosion product, sealant and water were measured (Figure 7). The results compare well with the calculated neutron attenuation coefficients, AlO(OH) = 1.5 cm^{-1}, H_2O = 2.7 cm^{-1} and explain the excellent contrast against aluminum Al = 0.086 cm^{-1}. A step wedge of Type 2219-T87 aluminum with thicknesses up to 150 mm enabled the importance of defect location (separation from image plane) to be measured, as a function of collimator ratio (Figure 8). This indicates that a two sided small source technique (L/D - 60:1, maximum separation 75 mm) might be as effective as a one sided reactor source technique (L/D - 120:1, maximum separation 150 mm).

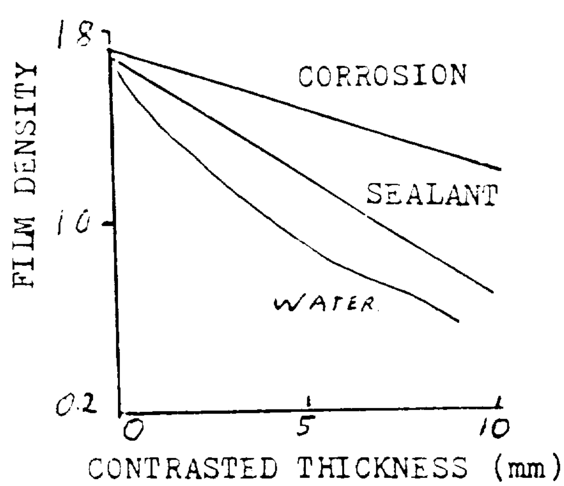


Figure 7
Measurements of neutron opacity of aluminum corrosion product, sealant and water.

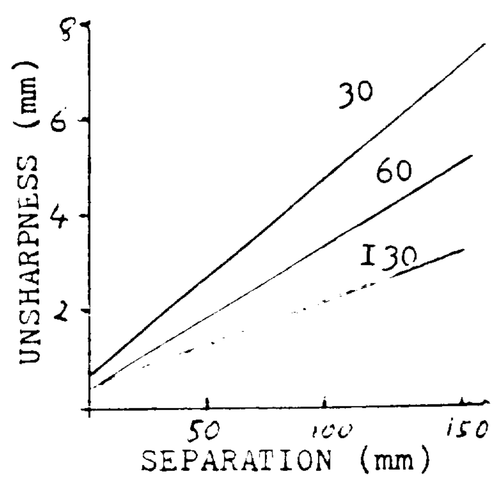


Figure 8
Measurements of effect of changes in defect to image plane separation on neutron radiography unsharpness - for different L/D.

The complex part geometry with the neutron transparent aluminum interspersed with many neutron opaque regions of steel and sealant makes clear the need to neutron radiograph each part through a flexible range of beam-part orientations. Moreover, image interpretation will be most reliable if radiographs at each programmed angle of orientation are compared with neutron radiographs taken for a standard (defect free or known defect) object. The comparative technique could also be valuable using n-ray scans and x-ray scans of the same objects. Because variable geometry scans will be most rapidly done using electronic imaging, the real-time systems based on Thomson image intensifiers and part positioners were tested both at the University of Virginia reactor (using L/D = 30:1) and at the McClellan AFB reactor (using L/D = 100:1). Figure 9 shows one large aft skirt segment for which electronic imaging capabilities have been demonstrated.

DISCUSSION

The fact that significant information can be obtained using a high intensity neutron beam from a nuclear reactor does not mean that the same is necessarily true for a lower yield neutron source such as a californium-252 isotopic source or a typical D-T accelerator. Such lower yield sources require the use of lower collimator ratios and/or faster film-screen combinations in order to obtain a film neutron radiograph within practical exposure times. An initial trial used the MNRS 50 mg Cf-252 source with L/D = 30. The imaging combination was Trimax-6 gadolinium oxy sulphide scintillator, and Kodak TMH film. The exposure time was fourteen minutes. This trial produced a neutron radiograph of the SRB segment that was significantly inferior to the reactor quality film taken with L/D = 100 using gadolinium metal-Kodak SR film.

Our first recommendation therefore, is to more thoroughly explore small neutron source technology to determine if this is a viable technology. If significant progress can be made using small segment test pieces from the SRB, then it could be recommended that an intact SRB aft skirt be shipped to the McClellan Air Force Base Maneuverable Neutron Radiography System for full scale tests using programmed robotics and comparative interpretation techniques. The purpose would be to proceed toward design of an inexpensive, non-reactor source neutron radiography custom designed for use by NASA, perhaps using the inside-outside dual robotics approach, previously proposed to NASA by USBI (Figure 10). A second step in this approach could be to take an existing mobile neutron radiography system to the NASA site for the trials on an intact SRB component. Either the Navy system[4], the Army system[5], or the LTV system[6] could be considered. The trials could be conducted in an area where a large controlled perimeter would avoid the need for radiation shielding or a special building.

If the required improvement in small source neutron radiography technology cannot be achieved the option open is to take more extensive SRB segment tests at a nuclear reactor, such as the Air Force SNRS. The first step would be to evaluate conceptual design and costs for a program to spot check intact SRB components on a reactor based neutron radiography facility.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

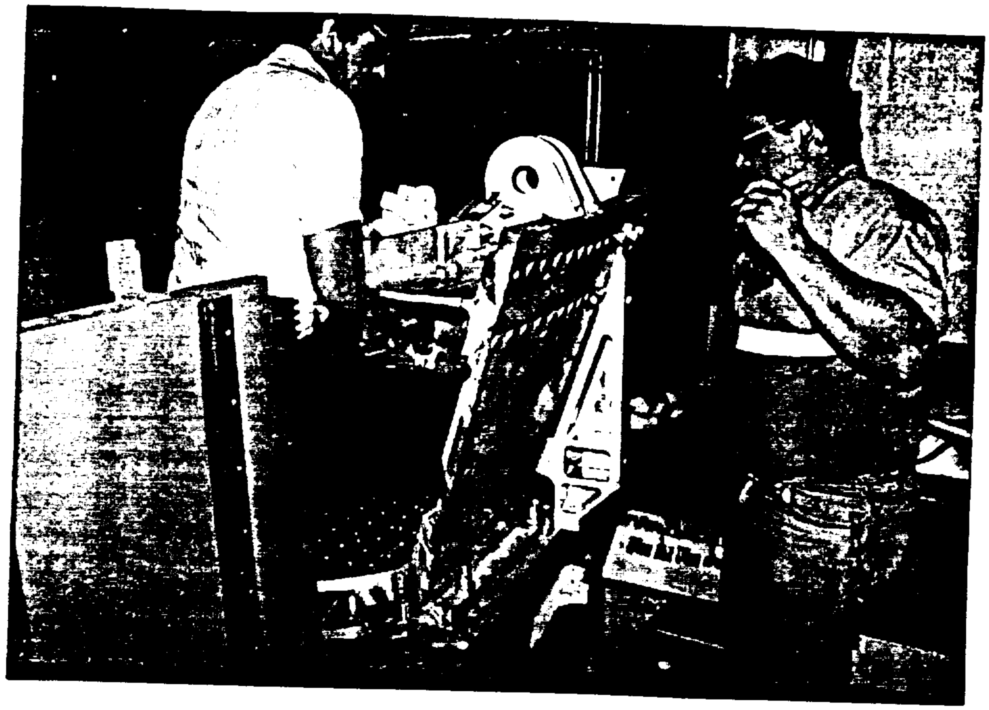


Figure 9: Photograph of a large segment from an aft skirt used in the electronic imaging method neutron radiography demonstrations.

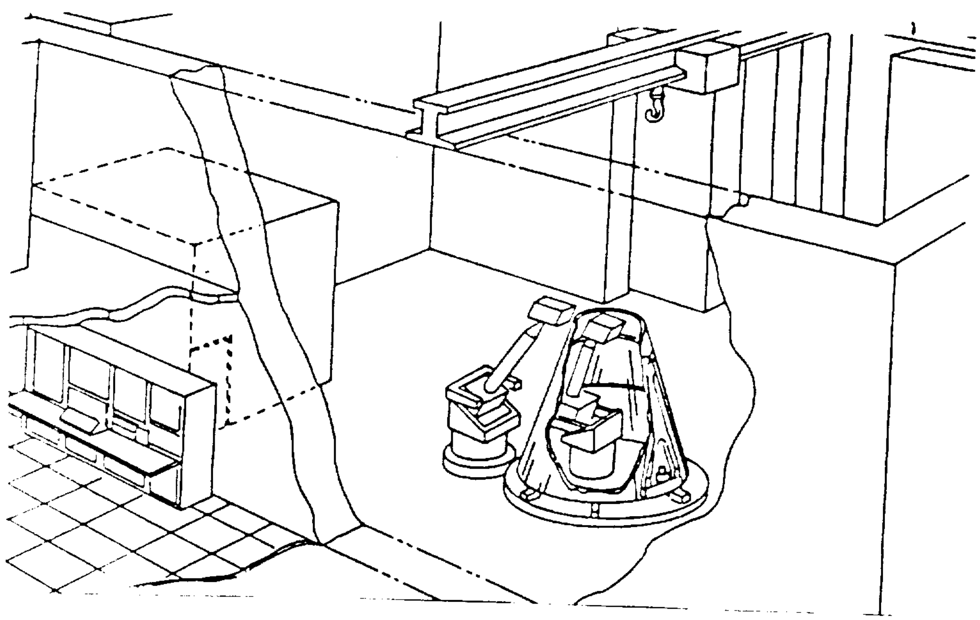


Figure 10: Conceptual design of a possible custom designed neutron radiography system dedicated to NASA applications.

REFERENCES

1. Golliher, K.G., "Neutron Radiography of Apollo Ordnance" in Neutron Radiography, Proceedings of the First World Conference, D. Reidel Publishing Co, 1983, pp 325-332.

2. Froom, D.A. et al, "Maneuverable N-Ray System Acceptance Tests" in Neutron Radiography, Proceedings of the Third World Conference, Kluwer Academic Publishers, 1990, pp. 741-748.

3. Froom, D. A. and J.P. Barton, "Aircraft Neutron Radiography - An Overview", in Neutron Radiography, Proceedings of the Third World Conference, Kluwer Academic Publishers, 1990, pp. 29-34.

4. Orphan V.J. et al, "Neutron Radiography of Aircraft Components using Mobile Neutron Radiography System", in Neutron Radiography, Proceedings of the Third World Conference, Kluwer Academic Publishers, 1990, pp. 749-760.

5. Antal, J.J. et al, "Experience with an On-Off Mobile Neutron Radiography System", in Neutron Radiography, Proceedings of the Second World Conference, D. Reidel Publishing Co, 1987, pp. 407-414.

6. Dance, W.E. and H.U. Mast, "Performance of Operational Mobile Accelerator Neutron Radiography System as Scale Factor for DIANE", in Neutron Radiography, Proceedings of the Third World Conference, Kluwer Academic Publishers, 1990, pp. 195-204.

NASA
National Aeronautics and Space Administration

Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle: Feasibility of Using Neutron Radiography to Inspect the Space Shuttle Solid Rocket Booster Aft Skirt, Forward Skirt and Frustrum, Final Report - Part I - Summary		5. Report Date: May 1992
		6. Performing Organization Code: AP43
7. Author(s): J.P. Barton, J.W. Bader, T.S. Brenizer, B. Hosticka		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address: NRE, Inc. 1422 Vue du Bay Court San Diego, CA 92109		11. Contract or Grant No.: NAS8-38681
12. Sponsoring Agency Name and Address: National Aeronautics & Space Administration Washington D.C. 20546-0001 George C. Marshall Space Flight Center, AL 35812		13. Type of Report and Period Covered: Contractor Report Final - Summary
		14. Sponsoring Agency Code

15. Supplementary Notes

Paper presented at the Fourth World Conference on Neutron Radiography, San Francisco, CA (WCNR-4) May 10-14, 1992

16. Abstract

The space shuttle's solid rocket boosters (SRB) include components made primarily of aluminum that are parachuted back for retrieval from the ocean and refurbished for repeated usage. Nondestructive inspection methods used on these aging parts to reduce the risk of unforeseen problems include x-ray, ultrasonics and eddy current. Neutron radiography tests on segments of an SRB component show that entraped moisture and naturally occurring aluminum corrosion can be revealed by neutron radiography even if present in only small amounts. Voids in sealant can also be evaluated. Three alternatives are suggested to follow-up this study: take an SRB component to an existing neutron radiography system; take an existing mobile neutron radiography system to the NASA site; or plan a dedicated system custom designed for NASA applications.

17. Key Words (Suggested by Author(s)): aerospace, aluminum corrosion, neutron radiography	18. Distribution Statement: Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Not Classfied	Not Classified	9	

NASA FORM 1626 OCT 86

ORIGINAL PAGE IS OF POOR QUALITY